FINAL REPORT

19980132

DETERMINING COST EFFECTIVE WAYS OF ASSIGNING MANAGEMENT UNITS WITHIN A FIELD FOR PRECISION FARMING

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Prepared by: Indian Head Agricultural Research Foundation (IHARF)

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Executive Summary

The objective of the project was to determine low cost ways of assigning management zone of differing productivity to a field. Upon identification of those zones, appropriate crop management practices would be developed in order to minimize production risks and unnecessary environmental risks.

Two methods were investigated. The first method involved extensive grid soil sampling and the second method involved the use of satellite imagery. The efficiency of delineating zones was determined using correlation with final grain yield. A combine equipped with a GPS unit and yield monitor was used to collect the yield data from the fields used in the study.

The first method was based on residual soil nitrate levels, crop yield and nitrogen removal from the previous crop. This approach was based on research done by Dan Long in Haver, Montana. This approach was not effective in delineating management zones since the correlation with crop yield in the following year was very low.

The second method involved the determination of Normalized Difference Vegetation Index (NDVI) derived from imagery from the Landsat-7 satellite. Using an unsupervised image classification method (Fuzzy K Means) it was possible to delineate zones and these zones were highly correlated to grain yield. More recent work has also shown that these zones responded differently to nitrogen fertilizer. It is therefore possible to develop management zones in a field with the use of satellite imagery and the costs are very low relative to soil sampling.

Profitability of the site-specific application of Nitrogen was evaluated by creating "Money Maps" from the yield maps by using the Saskatchewan Ag and Food crop planning guide figures. Results show that profitability of the wheat and Canola production increased with an increase in Nitrogen rates and in 2000 with an additional application of foliar fungicide for the wheat.

The findings from this research project could be of immediately use by producers. The approach developed would provide the opportunity for producers to focus more closely on the various identified zones in their fields and develop an appropriate management program for each zone. However new questions need to be answered such as: Is nitrogen the only nutrient to be varied? How do we manage fertility for each zone in a field? Can we use the same fertility management zones for applying crop protection inputs?

PART I

Site Specific Management: A remote sensing approach...

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ABSTRACT

The Indian Head Agricultural Research Foundation, a not-for-profit producer organization in Indian Head, SK, purchased 308 acres in 1997 to dedicate to Precision Farming research. Their interest was in developing protocols for delineating management zones within a field. The objective of the study was to find cost effective ways of assigning management units to a field without having to resort to a one-acre grid soil sampling and analysis approach which is very costly and time consuming.

The 308 acre field was divided into eight-38.5 acre parcels. A spring wheat - canola - spring wheat - field pea rotation was established such that each phase of the rotation was present twice resulting in a two replicate study. The size of the parcels allowed for the use of a commercial combine equipped with a yield monitor and GPS unit. It also allowed for the study of remote sensing imagery. A one-acre grid sampling scheme was superimposed on each field. A steel geo-referenced pin was inserted in the soil at each grid point for easy identification of the grids points. In 1998 and 1999, each field was treated uniformly in terms of fertilizer, seed and herbicide application to allow for the collection of baseline information. A variable rate nitrogen prescription map was superimposed on each spring wheat and canola field in 2000 and 2001 based on the nitrogen removal information from crops and soil test N levels or normalized difference vegetation index (NDVI) information from satellite remote sensing data from different sources (SPOT or Landsat TM or IKONOS). In this poster we are looking at the use of NDVI to delineate management zones.

Results of this study show that the correlation between NDVI and grain yield varies temporally as well as with crop types and source of data. Correlation between wheat yield and NDVI (extracted using satellite data from year 2000) varies between 0.05 to 0.8 whereas Canola yield and NDVI varies between 0.21 to 0.61 showing the usefulness of NDVI to be used as proxy of crop productivity.

Based on these relationships, management zones were delineated using NDVI extracted from 1998 and 1999 Landsat imagery using FUZME software. Optimal number of management zones were selected based on the variance reduction criteria using grain yield information. The result of this analysis identified four zones indicating variability in the crop vigor. The mean normalized yield in each of these zones were calculated as 0.29, 0.46, 0.48 and 0.66 respectively matching the conclusion of NDVI. The advantage of using information from secondary sources like satellite imagery are costs and availability of historical archived

information of the area of ones's interest as well as straight forward procedure to extract and use these information for site-specific management.

INTRODUCTION

The interest in site-specific management is a function of the possibility of applying crop inputs more efficiently with the desired end-result of increasing net returns. The greatest difficulty encountered with the concept of site-specific management is deciding which field measurements should be done and whether or not the variability measured has a strong relationship to final grain yield. Examples of measurements used in the past are grid soil sampling for macro-nutrients, soil electrical conductivity and digital elevation models. The obvious one is yield maps obtained from a combine equipped with a yield monitor and global positioning system. In order to obtain yield maps, you need to have access to the proper equipment which is not the case for many producers. There is also a lot of error associated with yield maps because of the positioning system and to a lesser extent the actual weighing system on the combine. The problem with all these measurements is the labour and costs associated in collecting the data.

In order to circumvent this problem, we have examined the merits of using remote sensing images as an indirect way of estimating grain yield based on measurements of biomass. The biomass estimation is based on the measure of normalized difference vegetative index (NDVI) which is a measure of the ratio of different wavelengths in the near-infra red and infra-red range ie. (NIR-IR)/(NIR+IR). The advantage with this approach is that the images are readily available and for a large number of years, depending on which satellite you are dealing with and the resolution at the field level ie. 30 m or less. The disadvantage is that some training in GIS and remote sensing is required in order to develop these maps which requires specialized software. However, companies do exist to deliver this type of product in a very cost effective way.

The objective of this study was to examine the feasibility of using NDVI measurements determined from satellite imagery and the clustering procedure of "Fuzzy K Means" (deGruijter and McBratney, 1988) for delineating management zones within a field and to correlate these zones to final grain yield obtained from a combine yield monitor and positioning system

MATERIALS AND METHODS

Field Study

In order to validate this approach, the Centre for Precision Farming at Indian Head was used as the test site (IHARF, 1999). The test site consists of a 308 acre field divided into eight fields of 38 acres (Figure 1). The area was seeded with the seeder attached with GPS guidance system (Figure 2). A spring wheat - field pea - spring wheat - canola rotation was superimposed such that each phase of the rotation is replicated twice. The fields were large enough so that it

was feasible to collect remote sensing imagery. The yield data was collected with a commercial combine equipped with a yield monitor and GPS unit(Figure 3) . At the start of the study in 1998, a one-acre grid was established over the entire study area. Each grid point was geo-referenced and a steel pin inserted into the ground for a permanent reference point. All subsequent field measurements taken were referenced to these pins. All crops were direct seeded into standing stubble and appropriate agronomic practises used for each crop. For more information about the study, please consult the website: http://paridss.usask.ca/precisionfarm

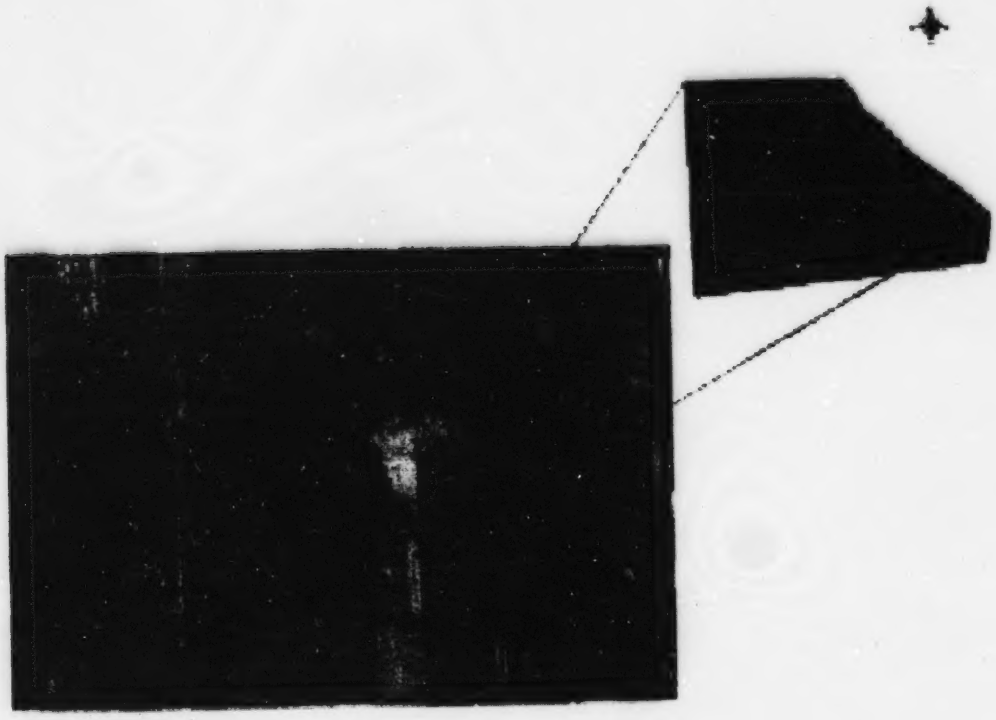

Figure 1. Aerial View of Site

Figure 2. No-Till Seeder Equipped with Variable Nitrogen Rate Capabilities.

Figure 3. Combine with Yield Monitor and Global Positioning System.

Data Analysis

Successful site-specific management requires knowledge about the in-field variability of soil properties and the response of crops to those properties. This can be achieve through intensive soil sampling and surveying. However, intensive sampling is costly and there is no guarantee that the information you are collecting is highly related to overall grain yield or can account for a significant proportion of the yield variability. In this situation, by using NDVI which is a measure of crop vigor, represents a variable that has a direct impact on crop productivity. The information, based on remote sensing imagery, is very easy to obtain, is relatively low cost and it is easy to extract the information.

As part of this overall project, remote sensing information was obtained from different sources i.e. Landsat TM (30 meter spatial resolution), SPOT (20 meter spatial resolution), and IKONOS (4 meter spatial resolution). Since red band (630 - 690 nm) near-infrared band (760 - 900 nm) are considered the most useful for calculating NDVI which is a measure of biomass accumulation (Lillesand Kiefer 1994). The NDVI is calculated from two channels using the relationship identified in equation #1.

$$NDVI = \frac{Value of Infrared Band - Value of Red Band}{Value of Infrared Band + Value of Red Band} \qquad (1)$$

The #1 equation produces NDVI values in the ranges of -1.0 to 1.0, where negative values generally represent clouds, water, and other non-vegetated surfaces, and positive values represent vegetated surfaces. The NDVI relates to photosynthetic activity of living plants. The higher the NDVI value, the more "green" the cover type. It means that the NDVI increases as the quantity of green biomass increases in an area. Once, the NDVI information from each of these sources were extracted. NDVI from these different sources were compared and correlated with N uptake after normalizing in order to remove difference in scale among the variables (Stevenson et al, 2001). The normalization were preformed as indicated in equation #2:

$$X_i = \frac{x_i - (\bar{x} - 2S.D.)}{4S.D.} \qquad (2)$$

Where:
X_i = The transformed value.
x_i = The observation i.
$\bar{x}$ = The mean of the observations.
S.D. = Standard Deviation

Grain Yield

Grain yield measurements were obtained using combine yield monitor. Yield information of wheat were extracted from the yield information of 1998 (field number 1, 3, 6, and 8) and 1999(field number 2,4,5, and 7). After normalizing, using Equation (2), both data sets were combined and a grid surface was generated using a krieging process (Isaaks and Srivastava

1989). The grid surface generated reveals the grain yield pattern of the spring wheat in the study area, which shows variation within and between experimental plots.

Clustering Process

In order to delineate management zones using NDVI information, imagery from the Landsat TM satellite for the years 1998 and 1999 was used to match the collected information on yields of spring wheat. The identification and delineation of management zones was done using an unsupervised classification or clustering method which helps in identifying naturally occurring clusters of data. The clustering algorithm used was the fuzzy k-means with extra-grades (deGruijter & McBratney 1988) which is a modification of fuzzy c-means (Bezdek, 1981). This modified algorithm is based on the assumption that continuous classes provide better representations of outliers or atypical individuals than discontinuous classes. This is especially the case with outliers located between clusters (i.e., intra-grades). Fuzzy k-means, for instance, will give intermediate memberships to intra-grades. However, outliers outside the main body of data points, referred to as extra-grades, are still not suitably represented by fuzzy k-means. deGruijter & McBratney (1988) modified the objective function to account for extra-grades. This improvement makes the memberships directly depend upon the distances to the class centroids. The classification was accomplished using the program "FUZME". developed at the Australian Centre for Precision Agriculture (Minasny and McBratney 2000). This software determines membership in each cluster through an iterative process beginning with a random set of cluster means. Each observation is assigned to the closest to these means. New means are recalculated for each cluster based on the distance (Euclidean, Diagonal, or Mahalanobis) from the observation to cluster mean. To ensure cluster stability, the process is repeated until either the specified convergence criterion is met or the maximum number of iterations, stopping criterion, fuzziness exponent, and distance metric is met. The software generates a data file containing each observation, the cluster to which it belongs, and a vector of membership values to indicate how closely each individual resembles each cluster. To obtain good convergence, a stopping criterion of 0.00001 was used in this study, which means the change in membership with an iteration of means calculation was less than 0.00001. Because, the variables used for classification exhibited significantly different ranges, the distance metric was set as to Mahalanobis. In this mode, the data set is transferred to one in which all attributes have zero mean and unit variance. Correlations between variables are accounted for as well (McBratney and Moore, 1985). The optimum number of zones were decided based on the fuzziness performance index (FPI) and modified partition entropy (MPE). FPI estimates the degree of fuzziness generated by a specified number of classes. MPE estimates the degree of disorganization created by a specified number of classes. Hence, both of these measures serve as a first step in determining optimum number of classes on the basis of minimizing these two measures (Roubens 1982).

Performance Analysis

Spring wheat yield information for 1998 and 1999 was used to analyze the performance of the optimal number of zones identified by the FUZME.

For better comparison, weighted yield variances for each zone based on the area of the zone (Fraisse and others 1999) as described below were used. The weighted variance was calculated using equation #3:

$$S_z^2 = \frac{1}{n_z} \sum_{i=1}^{n_z} (Y_i - \bar{Y}_z)^2 * \frac{n_z}{n_T} \qquad (3)$$

Where:
S_z^2 = Weighted variance for zone Z;
Y_i = Normalized grain measured for cell i;
$\bar{Y}_z$ = Mean of the normalized measured grain yield in the zone Z;
n_z = Number of cells in zone Z;
n_T = Total number of cells in the map.

The decrease in total within-zone variance was used as a decision criterion in selecting better information source. Total within-zone grain yield variance of a map was defined as the sum of weighted within-zone yield variances for each zone as indicated in equation #4:

$$S_T^2 = S_1^2 + S_2^2 + \ldots\ldots + S_z^2 \qquad (4)$$

RESULTS AND DISCUSSION

The correlations between grain yield and NDVI from different sources are presented in Table 1. NDVI from SPOT imagery taken at different times during the growing season shows the changes in the magnitude of the correlation with stage of crop growth. The relationship between NDVI extracted using Landsat TM data and crop yield shows a statistically significant correlation as well. Based on the availability of archived data, spectral resolution, cost of imagery and ease of information extraction,.Landsat TM was chosen as the data source. Though IKONOS data from a newly launched satellite has improved resolution (4 m vs 30 m), the major disadvantage is that the images always have to be pre-ordered, are more expensive and there is no way of accessing archived information. Accessing imagery from the SPOT satellite is also possible because archived information can be accessed, but the number of spectral bands are limited and it is more costly than Landsat TM.

Table 1. Pearson Correlation Matrix.

Field Number	Crop	SPOT June 29	SPOT July 26	SPOT Aug 15	TM July 26	IKONOS Aug 27
1	Wheat	*0.05**	*0.35*	*0.47*	*0.4*	*0.65*
2	Canola	*0.61*	*0.59*	*0.4*	*0.36*	*0.4*
3	Wheat	*0.74*	*0.88*	*0.73*	*0.77*	*0.74*
4	Peas	*0.8*	*0.92*	*0.04*	*0.89*	*0.21**
5	Peas	*0.53*	*0.68*	*0.27**	*0.49*	*0.1**
6	Wheat	*0.35*	*0.78*	*0.83*	*0.63*	*0.83*
7	Canola	*0.39*	*0.55*	*0.54*	*0.42*	*0.21**
8	Wheat	*-0.07**	*0.7*	*0.76*	*0.51*	*0.72*

* N.S. at 95%

Grain Yield

Grain yield measurements were obtained using a combine yield monitor . Yield information for wheat were extracted from data obtained in 1998 (field number 1, and 6) and 1999(field number 2,4,5, and 7). After normalizing, using Equation (2), both data sets were combined and a grid surface was generated using a Kriging process (Isaaks and Srivastava 1989). The grid surface generated reveals the grain yield pattern of the spring wheat in the study area, which shows variation within and between experimental plots (Figure 4).

Normalization resulted in the transformed grain yield information with mean 0.5 and standard deviation 0.25. With the normalization we were able to combine the both year information by removing the effect of unintended variation. After combining data these normalized yield information were used in creating grid surface using Kriging interpolation method. The results clearly shows the variation in the grain yield within each plot as well as between plots (Figure 4).

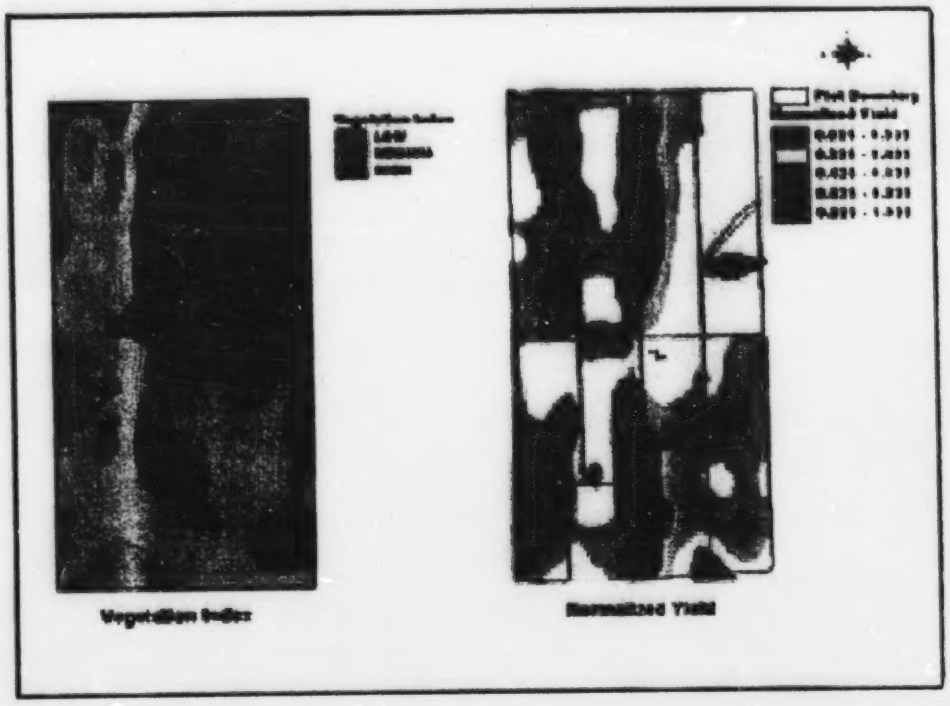

Figure 4. Normalized Grain Yield Based on 1998 and 1999 Spring Wheat Yield Information

Delineation of of Management Zones

The unsupervised classification procedure was used to delineate management zones. In this process, "FUZME2" software was used for the clustering portion of the study area behaving similarly and separating with dis-similar area. Explanatory variable vegetation index was used in this process with the assumption of it being a proxy for overall crop productivity. The software uses the fuzzy k-means algorithm for clustering. The algorithm requires users to define the minimum and maximum number of management zones to be delineated. In our case we defined 2 as a minimum and 16 as a maximum number of management zones. Based on user-defined criteria, the software assigns each points to a group. After classification, optimum number of management zones were determined based on the FPI and MPE index. The FPI is a measure of the degree to which different classes share membership and is constrained to values between 0 and 1. As FPI approaches 1, membership sharing increases. As the FPI approaches 0, classes become more distinct with less membership sharing. The MPE is an estimate of the amount of disorganization created by a specified number of classes. Like the FPI, it is also constrained to value between 0 and 1. As MPE approaches 1, disorganization predominates while values approaching 0 indicate excellent organization. Plotting the values of FPI and MPE against the number of classes and choosing a classification that minimizes both measures was the criteria used in the identification of the optimum number of zones (Figure 5).

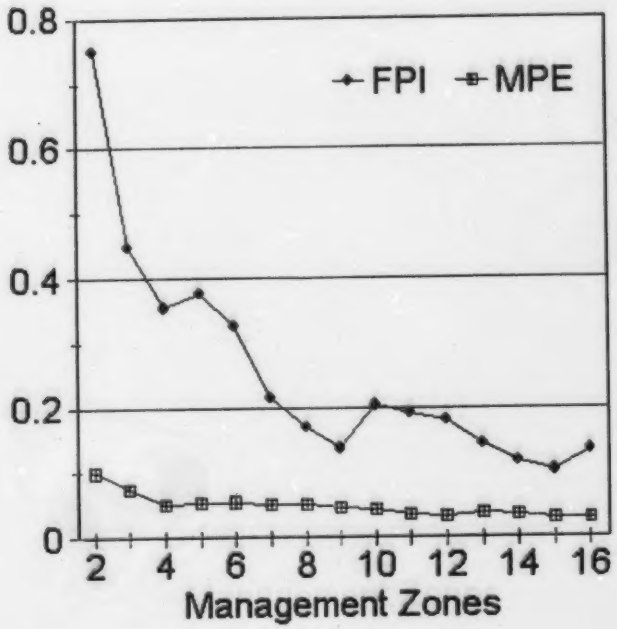

Figure 5. Plots of Clustering Performance Against the Number of Management Zones.

From the Figure 5, we observe that the decrease in FPI and MPE reaches maximum when it reaches 4 management zones, then the values start to decrease slowly. Hence, in our analysis we start comparing with four zones and end with eight zones for each option. Performance of each options were evaluated using the grain yield information which was also used to validate the zone identified by the FPI and MPE.

Performance Analysis

Based on the clustering performance shown in the Figure 5, we have chosen four management zones as the optimal number of zones. This selection of optimal number of management zones was based on the clustering performance and practicality in delineating and working within these zones. It can be seen from the Figure 5 that as the number of zones increase, both the performance index decreases and reaches zero when we delineate as many management zones as there are within-field variability. In essence, we will be able to get minimum variability if we treat every plant differently, which is practically and economically not possible. It may be feasible in for certain high value crops i.e.. premium win producing grape orchards. Hence, we have to balance the cost of having a large number of management zones and the net benefit generated from working with a large number of management zones.

Fisher's Least-Significant-Difference Test was conducted to compare grain yield means

from each zone. The results of this analysis showed that the mean yield inside each of the four zones were significantly different. Considering total variance of standardized grain yield without zone segmentation as 100 percent, total variance calculated for the four management zones delineated using Landsat TM information was 87 percent (Figure 6). This shows a reduction in the variance by 13 percent.

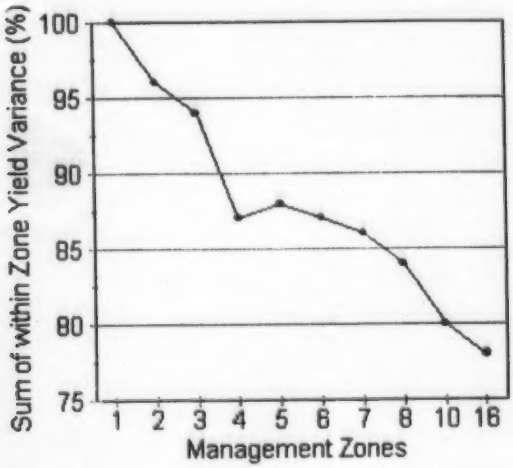

Figure 6. Optimal Management Zone Verification

Verification

Landsat TM imagery with a resolution of 30 meters is useful in providing information which can be used in the delineation of management zones (Figure 7). The advantage of using Landsat TM are it's availability and low cost . Another advantage of Landsat TM is availability of historical information from their archives, which may address the issue of the time required to collect sufficient information on a field before we can apply a proper management program to derive the full benefits of the field in question. With the recent introduction of Landsat TM 7, information will no longer be copyrighted which will allow producers to share information from a given scene. There also exists several agencies that can provide imagery at a cost of $0.12 per acre. Some additional costs will be incurred to process the data into useful products that can be accessed by variable rate application software.

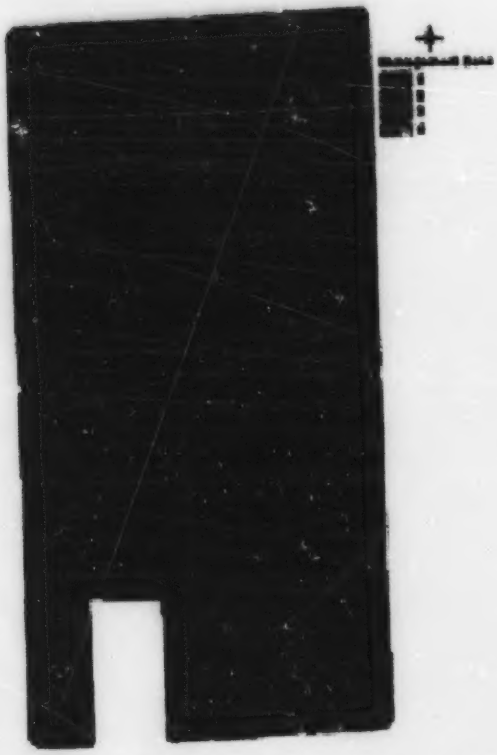

Figure 7. Optimal Number of Management Zones for the Center for Precision Farming at Indian Head.

CONCLUSIONS

The results of this study support the hypothesis that it is possible to develop management zones that relate directly to field productivity, in this case grain yield, based on NDVI derived from remote sensing data. Once the zones have been developed, the producer can then choose to vary inputs according to those zones. The producer will have to decide which input needs to be changed within each zones. This approach also allows the producer to observe carefully why the zones are producing differently and come up with reasons for these differences. Each field will be unique and as such a different approach will likely be required to capitalize on the unique potential of each field. This approach, because of the availability of past and present remote sensing images, would also allow a producer an assessment of the relative productivity of a neighbouring field that he may be contemplating buying.

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PART II
Profitability Evaluation of the IHARF Precision Farm Since 1998.

Introduction

One of the advantages of using GPS and yield monitor technology at harvest is the ability to map the yield variability on the go and to create yield maps. The yield information collected at harvest can be used, in conjunction with the Saskatchewan crop planning guide, to create "Money Maps" or "profitability maps" to illustrate profitable and non-profitable areas of a field.

The first step is to calculate the break-even bushel yield per acre needed to cover variable expenses and total expenses for a crop using the Saskatchewan crop planning guide for the year of interest. The second step is to use these figures to re-classify the yield map into 3 different classes: Class 1 - yield didn't cover direct cost, Class 2 - yield covered total costs and Class 3 - return to equity and create a money map (Appendix A). The third step is to query the "money map" to have an estimate of the area or percentage of the field for each class.

In 1998 and 1999 the Precision Farm was managed conventionally with a blanket application of fertilizers and crop protection products in a direct seeding system. In 2000 and 2001, a variable rate application program of liquid nitrogen was developed for the wheat and canola fields along with a blanket application of phosphate and sulfur fertilizers and crop protection products (refer to Appendix B for all cropping management practices from 1998 to 2001).

The crop break-even bushels per acre values for 1998, 1999, 2000 and 2001 were calculated using the exact cost for the seed and fertilizers at time of seeding (spring of each year), the average price for the crops sold and default values from the crop planning guide of the year of interest for all other expenses (refer to Appendix C for further details on commodity, seed and fertilizer prices and calculations). In 2000, each treatment was analyzed separately to obtain the break-even bushel/ac figures per treatment and overall field profitability was based on the comparisons between uniform and overall average of the variable rate strips. An application of Folicur was applied to the north and south third of fields 6 and 8. This application was taken into the profitability analysis.

Profitability Analysis

1998 Crop Production

Wheat:

Wheat production in 1998 was profitable as 88.1% of field 1 and 87% of field 6 showed a return to equity. The remaining areas of both fields showed a total cost recovery with no direct loss of profit.

Canola:

Canola production in 1998 was also profitable as fields 4 and 5 showed a net return of 70.9% and 54.3% of total area of the field respectively. 27.3% and 44.5% of total area of field 4 and 5 had yields that covered only costs and 1.8% and 1.3 % of the field areas respectively showed yield where revenues did not cover direct costs of production.

Peas:

Field pea production in field 2 was more profitable than in field 7 as 61.1% of the total area of field 2 showed a return to equity as compared to 10.3% for field 7. Total costs of production were recovered on 38.5% of field 2 and 61% of field 7 and an area of 28.7% of field 7 did not cover direct costs of production.

1999 Crop Production

Wheat:

Wheat production in 1999 was also profitable as 67.2%, 82.4%, 89% and 40.7% of fields 2,4,5 and 7 showed a net return and 32.6%, 17.3%, 10.9% and 57.3% of same fields had yields that covered only the cost of production. Very little or no areas of each field showed a negative revenue.

Canola:

Canola was the most profitable of all crops in 1999 as 88.8% and 99.8% of fields 1 and 6 showed a return to equity with 9.9% of the remaining areas of field 1 having yields that covered only the cost of production.

Peas:

Peas was the second most profitable crop grown in 1999 as 94.8% and 86.1% of fields 3 and 8 showed a net return and 3.9% and 8% of the respective field areas only covered costs. Field 3 seemed a little more profitable than field 8 as only 1.3% of the area of field 1 showed a revenue loss as compare to 5.9% of field 8. Parts of field 3 yield data was missing as yield monitor problems occurred during harvest.

2000 Crop Production

Wheat:

Profitability of wheat production in 2000 varied from field to field although general trends were apparent. In all four wheat fields, the return to equity increased from low to medium to high uniform N rate.

The north and south third of field 6 and 8 received an extra application of Folicur, a foliar fungicide. Break-even bushel/ac figures had to be calculated for the different part of those fields to accurately represent the profitability of the wheat production. In general, wheat production covered total costs in untreated areas but showed a return to equity when treated with Folicur. Furthermore, an increase in nitrogen application for the uniform strips showed a definite increase in return to equity in both Folicur treated and untreated plots. A very small area of each field showed a negative return that became insignificant when looking at the overall profitability of the wheat fields. More than 60% of the area of each variable rate strip of nitrogen in each of the fields covered total costs and 20% of the remaining area showed a return to equity.

Canola:

Canola production showed a net return on over 82% of the area of both fields in the uniform and overall average of the variable rate strip, with little or no revenue loss. The variable rate strips showed an increasing return to equity with an increase in nitrogen rate.

Peas:

Pea production showed a return to equity in 80.8 to 96.9 % of total field area of field 4 and 5 respectively. The difference in seeding rate (2 and 3 bushels/ac) did not have a significant effect on the profitability of field pea production.

2001 Crop Production
Wheat:

Profitability of wheat production in 2001 varied with the different nitrogen rates. In general, wheat production covered costs in 60% to 80% of the total field area in all fields. Return to equity was less than 10% of field area for all fields, and higher nitrogen rates (135 lbs n/ac and 150 lbs n/ac) showed an increasing revenue loss per area than the rest of the treatments. This phenomenon can be attributed to the low precipitation levels experienced during the 2001 growing season which did not allow the wheat crop to fully utilized the available nitrogen fertilizer.

Canola:

Canola showed an impressive return to equity in all nitrogen treatments due to high commodity prices. Return to equity varied from 87% to 100% of N treatment plots with as little as 0% to 10% area that covered total costs.

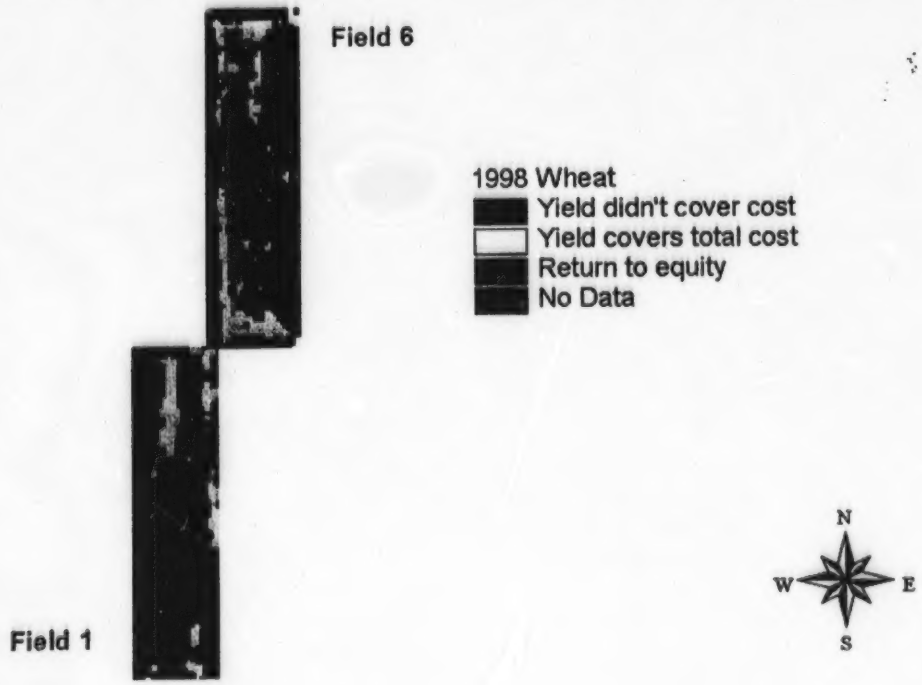
Peas:

Pea production had a greater return to equity in field 1 than field 6 due to the difference in soil available moisture present in field 1. However both fields showed a good return to equity (above 80% of field 1 and above 50 % of field 6) and no significant difference between seeding rates.

Appendix A

Profitability Maps of the IHARF Precision Farm.

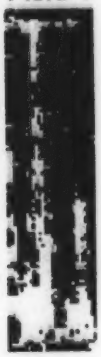
1998 Wheat Profitability Map.



1998 Canola Profitability Map.

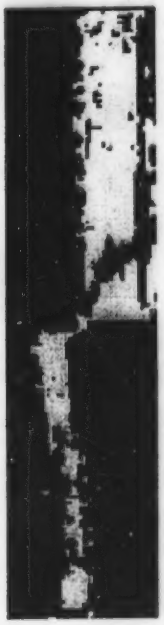
Field 5

Field 4



1998 Canola
- Yield didn't cover cost
- Yield covers total cost
- Return to equity
- No Data

1998 Peas Profitability Map.

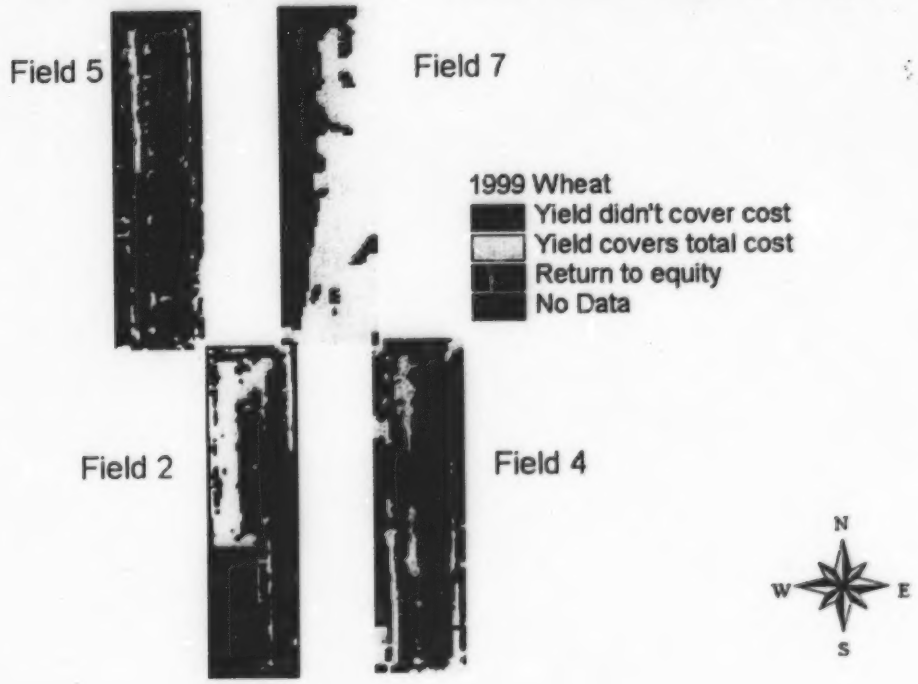


Field 7

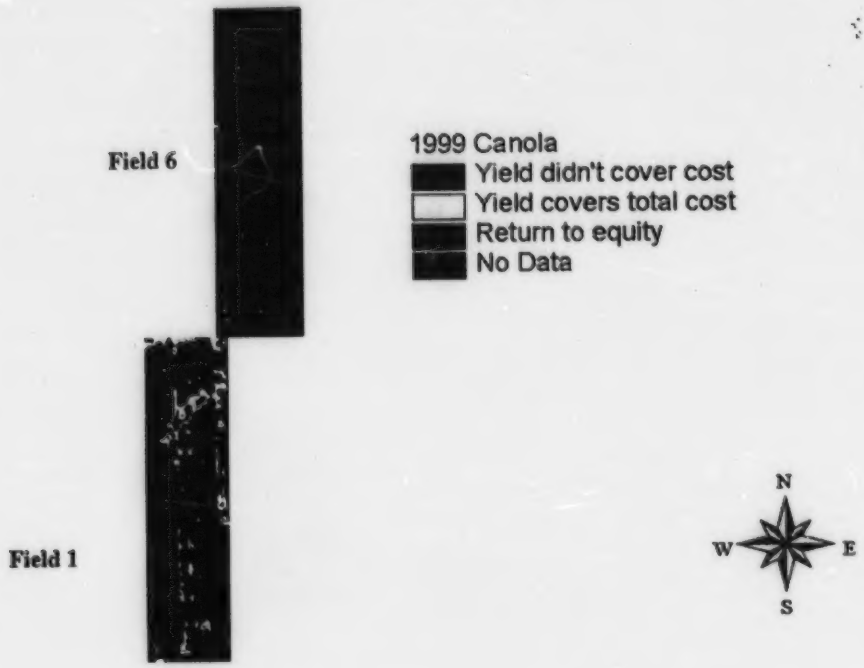
Field 2

1998 Peas
- Yield didn't cover cost
- Yield covers total cost
- Return to equity
- No Data

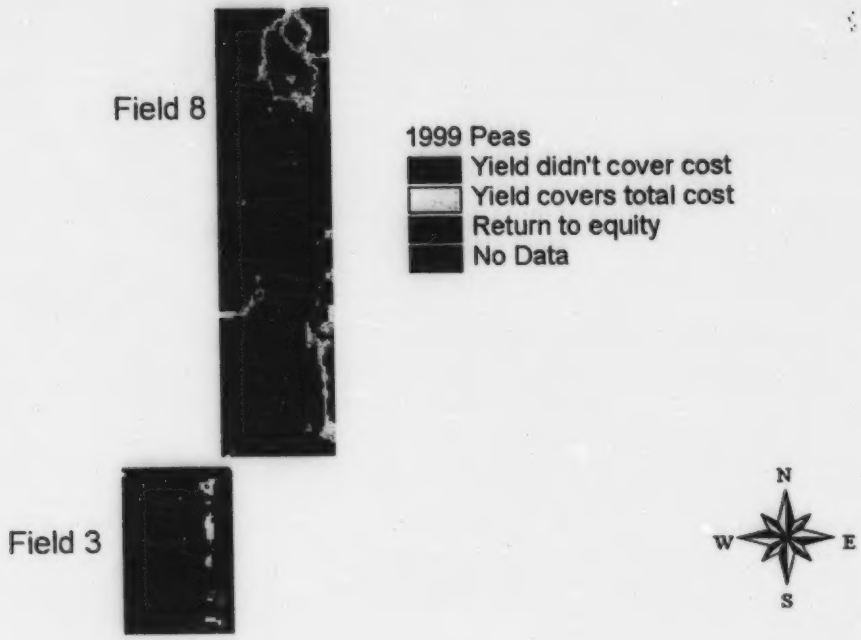
1999 Wheat Profitabilty Map.



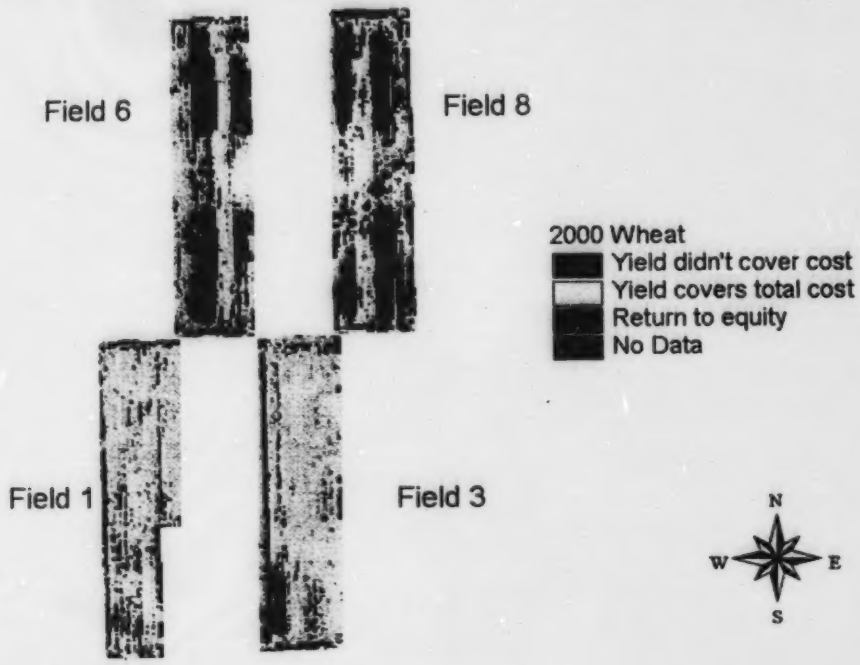
1999 Canola Profitability Map.



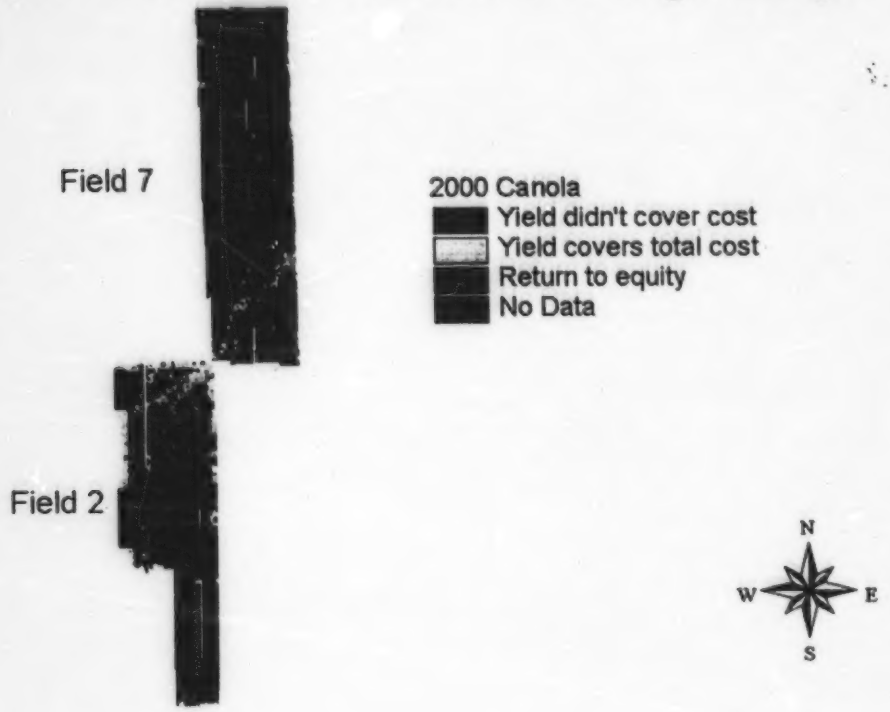
1999 Peas Profitability Map.



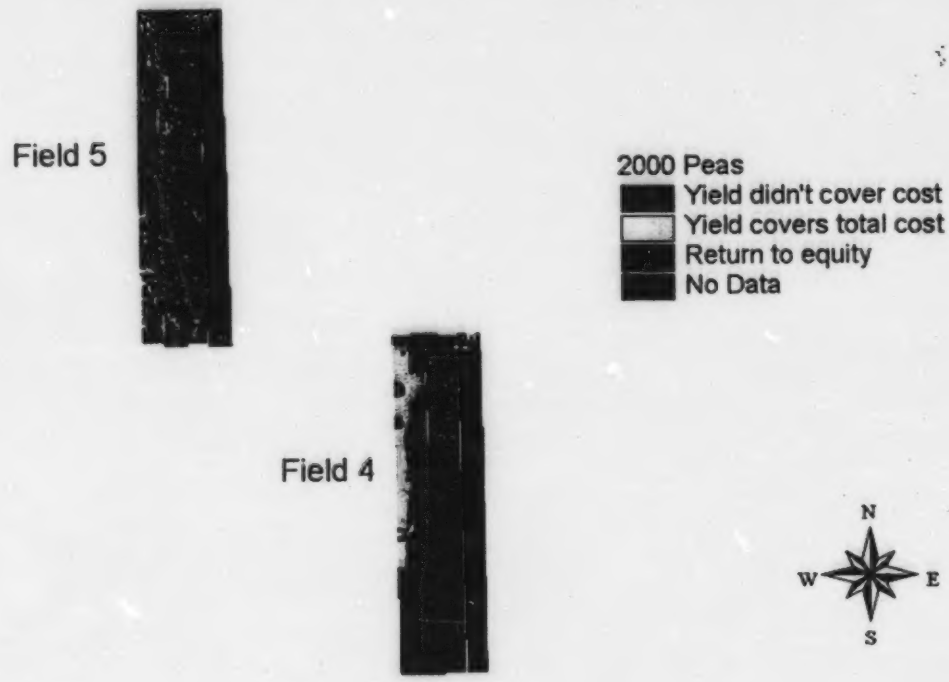
2000 Wheat Profitability Map.



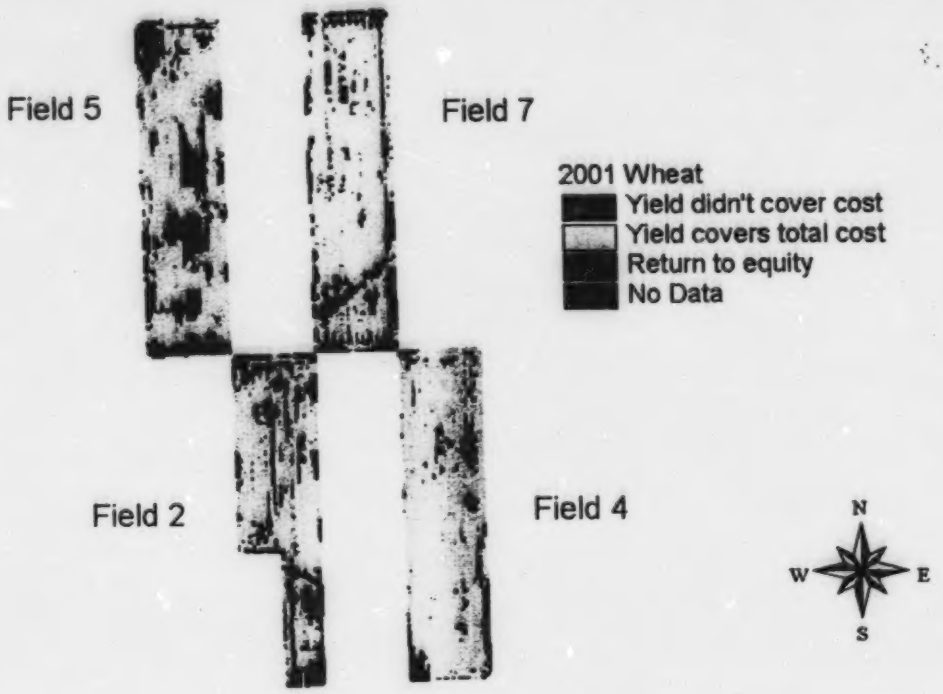
2000 Canola Profitability Map.



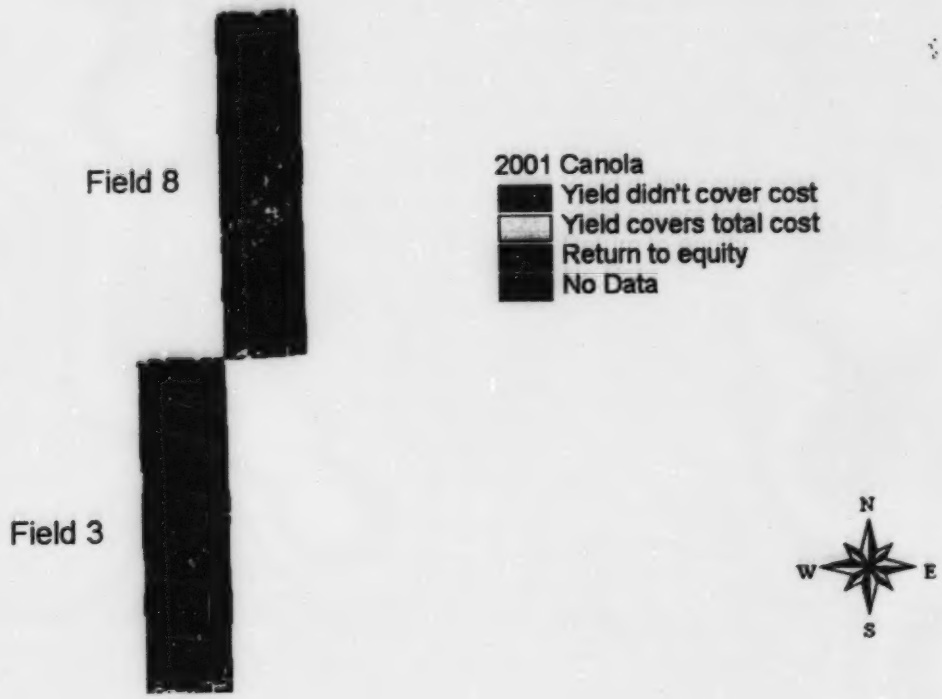
2000 Peas Profitability Map.



2001 Wheat Profitability Map.



2001 Canola Profitability Map.



2001 Peas Profitability Map.